BREEDING AND IMPROVEMENT OF CUCURBITS

T. W. WHITAKER, Associate Geneticist,
I. C. JAGGER, Senior Pathologist,
Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry

THE cucurbits—cucumbers, muskmelons, watermelons, pumpkins, and squash—belong to the family Cucurbitaceae. Botanically they form rather a homogeneous group. While they are extremely diverse in fruit and vine characteristics, their floral structures are in many respects very similar.

In general, the family is characterized by the flowering habit known as monoecious. A monoecious species or variety is one that bears its pistillate or female organs of reproduction and its staminate or male organs in separate flowers, both kinds of flowers occurring on the same plant. In the Cucurbitaceae the female and male flowers are easily distinguished, even before they open. The showy corolla, or petals, of the pistillate flower is attached to the end of an easily recognizable, small, undeveloped cucumber, squash, or melon as the case may be (fig. 1, *A*). The male flower is at the end of an ordinary flower stem, without any enlargement (fig. 1, *B*). The corolla surrounds the pistils or the stamens in the respective sexes.

Cucumber, squash, and pumpkin are normally strictly monoecious, but certain varieties of muskmelon and watermelon show a modification of this condition that is termed andromonoecious. An andromonoecious plant is one that bears bisexual or complete flowers, instead of strictly pistillate ones, in addition to purely staminate flowers.

Although at a cursory glance these bisexual, complete, or hermaphrodite flowers appear like ordinary pistillates, examination within the corolla will show the presence not only of the stigmas but of functional stamens as well. Such flowers can be self-fertilized by their own pollen, or by the pollen from a purely staminate flower or from another complete flower on the same plant.

Our knowledge of the genetics of the cucurbits is very meager and fragmentary. There are several reasons for this. Probably the most important one is economic. The plants are large, and the space required to produce the numbers demanded for statistical significance in genetic experiments is enormous. Recently, however, promising results from systematic breeding programs with melons, watermelons, and squash have enriched our knowledge of the fundamental genetic nature of these crops (*13*),[1] and this in turn should be useful in further breeding work.

[1] Italic numbers in parentheses refer to Literature Cited, p. 231

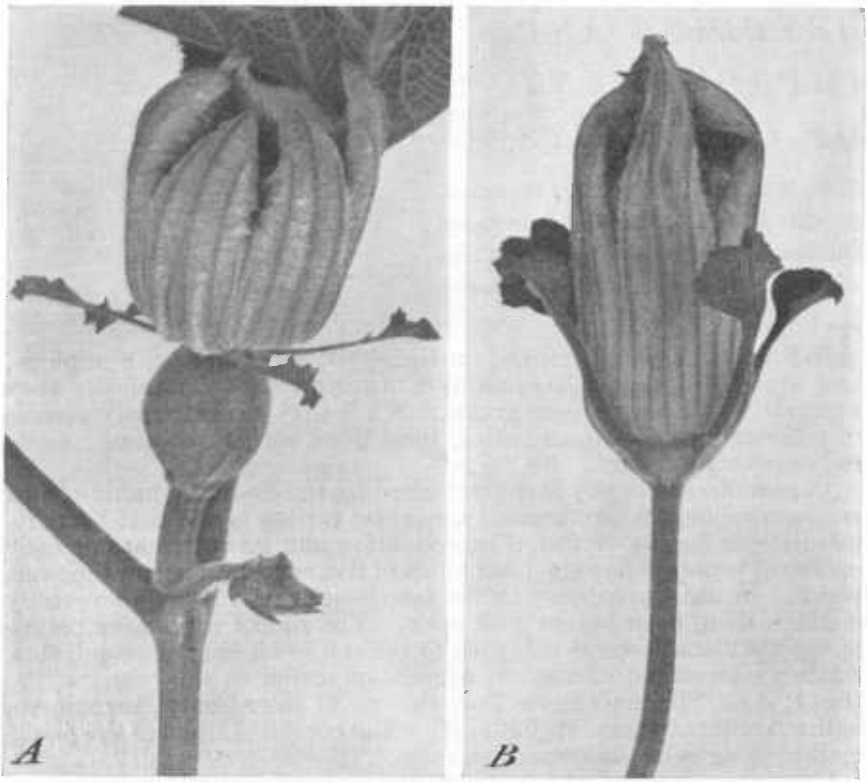

Figure 1.—Squash blossoms, structurally typical of the cucurbits: *A*, pistillate flower showing undeveloped fruit to which the corolla is attached; *B*, staminate or male flower.

BREEDING RESPONSES AND POLLINATION TECHNIQUE

STUDIES made by numerous investigators of the cultivated cucurbits show that the several species are alike in certain breeding responses and variations in reproductive behavior. These points may well be treated here, since they seem to apply to the several crops.

Haber (*8*), working with Des Moines squash, a trailing variety of *Cucurbita pepo* L.; Scott (*25*) with three bush types of *C. pepo* (White Bush Scallop, Giant Summer Crookneck, and Zucchini), and also (*23*) with muskmelon; Porter (*18*) with watermelon; Cummings and Jenkins (*3*), with Hubbard squash, a variety of *C. maxima* Duchesne; and other investigators have shown that loss of vigor does not necessarily follow as a result of inbreeding these plants. This is quite contrary to the usual situation with normally cross-bred plants. Scott and Porter have shown that inbred lines having greater, equal, and less vigor or size of fruit may all be isolated from a given individual and that no difficulty may be expected from self-sterility in such inbreds. The work of Rosa (*21*), of Scott (*25*), and of Porter (*18*)

indicates that hybrid vigor does not occur as a result of crossing inbreds—also contrary to what might be expected.

Rosa (*20*) has sought evidence of metaxenia in muskmelon and Hibbard (*9*) in squash, but no such phenomenon was observed in either case. Metaxenia here refers to an immediate effect of pollen upon the character of the fruit or gross seed characters.

The constancy of these results for a wide range of varieties among several species of the cucurbits is rather conclusive evidence against the loss of vigor from inbreeding or the occurrence of hybrid vigor or of metaxenia in any of the cucurbits discussed in this article.

Another characteristic common to cucumber, squash, muskmelon, and certain other cucurbits is the wide variation within varieties in the ratio of male and female flowers. This ratio is profoundly influenced in many varieties of cucumber by changes in season (length of day) and in nutrients (*5*, *29*); and in squash by season and load of developing fruits borne by the plant (*24*). Under certain unfavorable conditions some varieties may become almost monosexual (all pistillate or all staminate), so that the investigator has great trouble in obtaining the desired set of fruit and seed.

Whitaker (*32*) has published a brief review of the literature on this subject, together with data on the typical sex expression of 49 varieties of cucurbits in 8 species and 4 genera and on deviations from typical expression in each species. His data showed very wide fluctuations in the ratio of male to female flowers in the several varieties and species. He concluded that sex determination in these cucurbits appeared to conform to Correns' theory as applied to monoecious flowering plants. According to this theory the gene complex for maleness may be represented as *A* and that for femaleness as *B;* another gene or complex, which may be indicated as *Z*, determines the sequence of activation or expression of *A* and *B*. *A* and *B* in themselves are believed to be relatively stable, but *Z*, which represents

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TWELVE *years ago, powdery mildew suddenly appeared in destructive form on melons in the Imperial Valley, Calif., the leading muskmelon-producing section in the United States. It could not be controlled by fungicides, and plant breeders began a search for disease-resistant material. In 3 years of careful testing they discovered several resistant varieties among melons imported from India. They were poor melons, but by suitable crosses their resistance to mildew was bred into good American varieties, and in another 4 years the first of the hybrids was released to California growers. Four more years of selection gave Powdery Mildew Resistant Cantaloup No. 45, which has superior shipping qualities in addition to disease resistance. This was released to growers in 1936, and the mildew problem is now largely solved in this area.*

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the factors controlling the expression of maleness and femaleness, may be responsible for a reaction to environment that results in stimulation or retardation of *A* or *B* within very wide limits.

The pollination technique developed by Porter (*18*), working with watermelons, illustrates the general method employed in making controlled pollinations with flowers of the cucurbits. Approximately 24 hours before the flowers open, pistillate and staminate flowers are selected and covered with small muslin bags (in the case of melons and cucumbers, 1-pound manila bags are satisfactory). As soon as possible after the flowers open, the staminate flower is removed and its pollen is applied to the stigma of the pistillate flower. After pollination, the pistillate flower is covered with a 1-pound manila bag, held firmly in place by string or a paper clip. The pollination data are written on a tag attached to the flower, or directly on the paper bag. Several days after pollination the bags are removed, the fruit is tagged, and its location is marked by a stake.

It has been found unnecessary to cover the staminate flowers with a bag before they open. By placing a string around the corolla the flower is prevented from opening, and insects cannot enter. This eliminates one step in the process and increases the number of flowers that can be pollinated in a given length of time. Hermaphrodite flowers that are to serve as the female parent in a cross must not only be bagged before they reach full bloom but emasculated before the anthers shed pollen, to prevent self-pollination. Since the anthers may discharge pollen 24 hours before the flowers open, emasculation should be done more than 24 hours before opening. Purely pistillate flowers that require no emasculation need not be bagged before pollination, but the corollas may be tied shut as described above.

CUCUMBERS

THE cucumber, *Cucumis sativus* L., is supposedly a native of India (*30*), although plant explorers have never been able to discover a wild prototype. Cucumbers have been cultivated since earliest antiquity. Reliable records indicate that they were used as food in ancient Egypt, and were a popular vegetable with the Greeks and Romans. They are very important staple vegetables among the Russians and many orientals. In the United States cucumbers are widely grown in home gardens, in local-market gardens, and on truck farms for shipping, but in spite of their wide distribution under cultivation, their commercial importance is not so great as that of some of the other cucurbit crops.

VARIETAL IMPROVEMENT

Cucumbers are usually divided into two classes according to use—slicing varieties and pickling varieties. This distinction is maintained even though the slicing variety may be used for both purposes. The plants of slicing varieties produce a moderate number of medium-length thick fruits generally with white spines. The pickling varieties are characterized by the production of very numerous, small, black-spined fruits. The fruits of most pickling varieties are so small, while still immature, that they are not adapted to slicing.

In England, a special forcing type of slicing cucumber is grown in greenhouses. This type sets fruit without any pollination and the fruits attain great length—over 2 feet in some varieties. Unless pollination is insured, the fruits are seedless, straight, dark green, and generally spineless. American consumers, however, do not like the huge English type, and American greenhouse varieties are either of the White Spine slicing type mentioned above or of an intermediate hybrid type somewhat longer than White Spine and darker green. Most growers of greenhouse cucumbers in this country use especially adapted strains; many use their own selections.

With one exception, all of our extensively grown commercial varieties of cucumber are the results of breeding, selection, or introduction by private growers and seedsmen. Many of the names commonly listed today are very old and represent varieties introduced from Europe. The origin of very few varieties is a matter of record, even in the case of comparatively recent introductions. Confusion in names is perhaps more extreme in cucumber varieties than in many other crops because of the ill-defined nature and lack of stability of so many of the supposed varietal characteristics. Vine habit, bearing habit, fruit size, shape, and color are all subject to marked variation under different conditions of culture, making the identification of varieties difficult. In all cucurbits, natural cross-pollination within a species complicates the problem of maintaining the purity and uniformity of stocks and varieties, but mixtures are especially difficult to detect in cucumbers because many so-called varieties have few really distinguishing features. With the exception of special greenhouse types and novelties, there are probably not over 15 to 20 really distinct cucumber varieties grown in this country.

It is questionable whether many of the supposedly superior varieties introduced successively in the last 50 years represented improvements distinct enough to justify new variety names. Seedsmen and growers have long attempted to develop varieties that will produce fruits of good size, uniform cylindrical shape, and attractive dark-green color before they begin to show signs of full maturity. Color is especially important because paleness or a yellowish tinge suggests too advanced maturity. A uniform dark green is most desired, and of course the flesh must be tender, crisp, and free from objectionable flavor.

A more recent breeding objective, not yet realized, is to develop varieties with a wide range of adaptability and resistance to various adverse conditions that result in low yields and poorly shaped fruits.

Early Cluster, Early Frame, Early Russian, Long Green, and White Spine were listed by the earliest seed catalogs in the United States, and have been grown here for at least 125 years. The first three are small, early, prolific varieties typical of the black-spined type; the last two bear larger, less numerous white-spined fruits that are more like the present popular slicing varieties. The origin of none of them is known.

Improved Long Green is a very long (12 to 13 inches), black-spined, dark-green, slightly tapered, late variety selected from London Long Green by D. M. Ferry & Co. and introduced in 1872. Arlington White Spine, a selection from White Spine that appeared about 1880,

is still a leading strain of White Spine. It is about 8 to 9 inches long, 2½ inches in diameter, medium green, and has a tendency to turn pale green or white at the blossom end. Davis Perfect (1905) was originated by Eugene Davis, of Grand Rapids, Mich., from a cross between White Spine and Telegraph, an English forcing variety. Davis Perfect is about 10 inches long, 2½ inches in diameter, white-spined, smooth, dark green, and distinctly tapered at both ends. Fordhook Famous, introduced by W. Atlee Burpee & Co. in 1902, was originated by A. McInnis, a grower in Ontario, Canada, who selected it from a cross of White Spine and Noa Forcing, made about 1894. It is a typical White Spine type, showing but little of the Noa Forcing character. Early Fortune was selected from a field of Davis Perfect by George E. Starr in 1906 and introduced by the Jerome B. Rice Seed Co. This has been an important and popular White Spine type for many years on account of its desirable size (about 8½ by 2½ inches), attractive cylindrical shape with rounded ends, good retention of green color, and productivity. Other popular current varieties are Stays Green or Black Diamond, Klondike, and Longfellow. The origin of these is obscure.

Deltus, a popular forcing variety, was obtained from a cross between White Spine and Tailby Hybrid made in 1896, the progeny of which was later crossed with Long Green. Adelbert Titus, a grower near Rochester, N. Y., originated the variety. Another popular variety of the Rochester district is the Irondequoit, developed by J. H. Wirt & Sons from a cross of White Spine and Telegraph made in 1904. In 1929 the New York Agricultural Experiment Station at Geneva, N. Y., introduced a parthenocarpic (seedless) variety named Geneva. It was developed from a cross of Arlington White Spine × Rochford Market made in 1916. All three of these are intermediate between the White Spine and the English types.

It is evident that the old White Spine is involved in the parentage of nearly all the slicing varieties grown in this country, both field and greenhouse types. Except in cases of known hybridization with Black Spine or English forcing sorts, one might be justified in considering all our white-spined field types simply as strains of White Spine.

Of the pickling type, Boston Pickling (1865), Chicago Pickling (about 1880), National Pickling (1929), and Snow Pickling (1906) are by far the most important. The first two are selections from unknown varieties grown near the places of origin indicated by the names. Snow Pickling was introduced by J. C. Snow, of Rockford, Ill., in 1906. National Pickling was developed by George E. Starr, of the Michigan Agricultural Experiment Station (1929), to meet the specifications of the National Pickle Packers' Association, who cooperated with the station in the work. The pickle packers desired a variety producing a large number of small, black-spined, dark-green fruits, similar to Snow Pickling but more nearly cylindrical or blocky, having the same diameter well out to the ends instead of being slightly tapered. These specifications are of special interest to those who pack pickles in glass containers and desire the most attractive product possible.

Disease Resistance

Reference to the appendix at the end of the section on vegetables in this Yearbook will show that several investigators, both in the United States and abroad, are trying to develop good commercial varieties having resistance to one or more of several diseases, particularly mosaic, downy mildew, and bacterial wilt.

Mosaic is a serious problem wherever cucumbers are grown in the Central, Eastern, or Southern States, particularly in the areas devoted to pickling varieties. Losses of 15 to 30 percent of normal production may be expected annually, and in many isolated cases much heavier losses occur.

Downy mildew is generally distributed. It is especially severe in the South, where it is in effect the dominant limiting factor in cucumber production. The losses usually depend on how early the disease attacks the plants, for it occurs every year and terminates harvesting soon after it becomes established in a field. Thorough spraying two to three times weekly is often an inadequate although a very expensive attempt at control.

Bacterial wilt is a serious disease, in the Central and Eastern States in particular. Plant pathologists estimate general losses to be 10 to 20 percent of a normal crop, while often certain fields may be practically a total loss.

The Bureau of Plant Industry has obtained a number of stocks of oriental varieties of cucumbers, chiefly from China, Japan, and India, some of which contain distinctly disease-resistant individuals. Considerable tolerance to mosaic has been found in certain inbred lines, and in some a measure of resistance to mildew and to wilt. High-quality American susceptible varieties have been crossed with the low-quality resistant kinds and the hybrids back-crossed to the American parents. Inbreeding is also being continued in efforts to isolate lines that are pure (homozygous) for resistance to specific diseases.

Bailey and Burgess, at the Maine Agricultural Experiment Station, are engaged in breeding cucumbers resistant to scab. This disease causes very severe losses by spotting the fruits, making them unsalable, as well as by reducing yields. It is confined almost entirely to the northernmost States. Inbred lines of commercial varieties are subjected to artificial inoculation to determine resistance or susceptibility. A number of lines apparently homozygous for resistance have been isolated. Preliminary studies indicate that resistance is dominant and due to a small number of factors, possibly only one.

MUSKMELONS

It is generally believed that the muskmelon (*Cucumis melo* L.) is native to India (*30*). Although there are indications that it was in use about the beginning of the Christian Era, it is not believed to have been in cultivation in very ancient times.

From its center of origin in northwest India it spread to China and Japan but has not reached a high state of development in those lands. To the westward, in Iran (Persia), in Turkistan, and in other regions of Asia Minor and about the Mediterranean, it was developed to a very

high state of perfection. Columbus first brought the species to the New World, and the natives of the West Indies and the mainland of North America quickly adopted it. By 1535 it was grown by the Indians as far north as Montreal, Canada.

Although the muskmelon is grown in every State, most of the commercial production is concentrated in a few sections of southern California, Arizona, Colorado, Texas, Michigan, and Indiana and in the tri-State area of Maryland, Delaware, and New Jersey.

There is a large number of varieties of muskmelons under cultivation in the United States. Many of them closely resemble one another, and improved forms are gradually replacing the older varieties. Muskmelon varieties may be arbitrarily divided into two classes—(1) shipping or commercial melons and (2) local-market and home-garden melons. Most shipping varieties produce comparatively small fruits with a tough rind and firm flesh and are adapted for shipping in standardized packages to distant markets. Local-market melons generally have softer flesh and are often large.

The name "cantaloup" is quite generally used in the United States to designate the small, oval, netted shipping type of muskmelon. Much confusion over the term has resulted from the fact that in Europe it is applied to a different type of melon, a long-keeping sort with a hard, ridged or warty rind, practically unknown to American growers (*14*). The American usage is now so well established that we must accept the name cantaloup as defined above. Obviously all cantaloups are muskmelons, but many varieties and types of muskmelons are not cantaloups by this definition. The kinds that lie outside the definition are the winter types, as Persian, Casaba, and Honey Dew, the Honey Ball, and the large, ribbed sorts like Bender and Montreal.

Varietal Improvement and Breeding

The number of varieties of muskmelon that have been and are being grown in this country is so great that no attempt to review the early history and development of all of them can be made here. Only the leading present varieties and a few of their supposed progenitors can be discussed, together with a brief reference to certain kinds that were formerly important.

Prior to 1850 most of the few varieties of muskmelon then grown in this country were introduced from Europe. Efforts were begun prior to that time to improve the crop from the standpoint of adaptability, particularly to the northern part of the country. Increased earliness and productivity were of special interest, since most of the imported varieties then available were apparently from warmer regions or for greenhouse culture. Nutmeg and Pineapple appear to have been varieties similar to our present cantaloups, and apparently the famous Netted Gem—later called Rocky Ford—was derived from the latter. Pineapple was described by Burr (1865) as roundish to oval, without ribs or with ribs faint, size small, skin olive green with abundant net markings. Nutmeg was described as slightly larger, ribbed, and otherwise similar. Both were old well-known European types. Most sorts described at that time were large, heavily ribbed, and netted. Numerous melons of the winter Casaba

or Persian type were described, but there is no indication that they were important. Most of the supposed American varieties mentioned by Vilmorin in 1856 were indicated as being related to the "American" variety Pineapple.

One of the earliest instances of muskmelon improvement in this country was the origination of the Christiana melon. It was developed about 1835 by Josiah Lovett, of Beverly, Mass., and is supposed to have been a cross of the variety Green Malta and an unnamed early sort. Despite poor quality, it was popular because of its earliness and was commonly listed for over 75 years.

About 1875 keen interest in muskmelon improvement was shown by both seedsmen and growers for the market, but the latter were perhaps the more active in actual selection and hybridization. Little artificial pollination appears to have been done, but natural crossing in mixed plantings furnished these growers with an abundance of material for selection.

About 25 rather distinct varieties besides the winter melons are of commercial importance or considerable home-garden interest and are listed by the leading seedsmen of this country at present. About a third of these are over 50 years old and only a half dozen are less than 25 years old. This survival indicates that the old "practical breeders" achieved results not easy to surpass and that the introducers brought in varieties well adapted to cultural conditions and consumer tastes. In 1901 there were about 25 or 30 fairly distinct and important sorts commonly listed, and about half of these are still current.

The old Surprise, of unknown origin, was introduced in 1876 and is supposedly the parent of Bender Surprise, a large, prominently ribbed sort that is an important home and market melon of the Northern States today.

The Netted Gem, apparently a form of the very old Pineapple, was first listed by W. Atlee Burpee & Co. in 1881. Its notably successful adaptation to shipping and market needs stimulated a great deal of interest in obtaining different and still better varieties of the same general type. Varieties of this type, with different flesh colors, slightly different sizes and shapes, and adaptability to different regions, soon were developed in the commercial muskmelon areas.

In 1886, Acme or Baltimore was introduced by J. Bolgiano, of Baltimore, and Emerald Gem, by W. Atlee Burpee & Co. Anne Arundel, introduced by Griffith & Turner, of Baltimore, in 1894, was believed to have been selected from Acme. About 1905 another selection, apparently from the Acme-Anne Arundel line of development, was introduced under the name of Sweet Air by George Tait & Sons, of Norfolk, Va. This same variety had been sold in Maryland as Knight for some years. The two names are known to be synonymous and the variety is still widely grown in the Chesapeake Bay section.

In 1897 the Netted Gem was renamed Rocky Ford to advertise its merits as grown and shipped by a group in the Rocky Ford, Colo., district, whereupon it became more popular than ever. When it proved to be adapted to the Imperial Valley, that desert area having been placed under irrigation a few years later, a truly phenomenal development of the cantaloup industry began. Several years later, green-

fleshed selections with salmon-tinted cavity were made from Netted Gem or Rocky Ford and appeared as Salmon Tint and Pollock 10–25; and deeply salmon or orange-fleshed selections appeared as Perfecto (1919) and Superfecto (D. V. Burrell & Co., 1926). These improved varieties of the Netted Gem type are more nearly spherical, more heavily netted, and thicker fleshed than the parent variety, and the present vogue is for solid salmon-colored flesh. They also differ somewhat in adaptation to climate, culture, and handling methods.

Hale Best, introduced in 1924 by I. D. Hale, became the leading commercial or shipping variety. It was developed by selection from a mixed stock obtained from a Japanese gardener in the Imperial Valley. The vines are medium in size; fruits small, usually weighing 2 or 3 pounds each, oval to round, slightly ribbed, well covered with dense heavy netting; flesh thick, firm-textured, solid salmon in color. Hale Best is the earliest of the high-quality shipping melons. The variety was quite variable when introduced, but improved forms have been and are being developed. Hale Best No. 36 and Hale Best No. 112 are popular strains at present. Since the variety is susceptible to mildew, it is certain to be displaced, at least in the Imperial Valley, by the new mildew-resistant varieties.

Hale Best is similar to Perfecto but is usually a few days earlier. The fruit is somewhat larger and the flesh possibly firmer, and it tends to hold up in shipment longer than Perfecto. Superfecto and Perfected Perfecto (Garwood & Woodside, 1925) are improved strains of Perfecto.

It is rather striking to note how the old Acme type and its elongate, green-fleshed descendants have tended to dominate the field in the Middle Atlantic States while the Netted Gem and its nearly round, salmon-fleshed derivatives have moved West and dominated that area from the beginning of the industry. Two other types or lines of development, from Osage, are also of particular interest, since the varieties that have resulted from them compete more or less with the two types just mentioned.

The Osage was originated by Roland Morrill, an active muskmelon breeder of Benton Harbor, Mich. It is claimed that it was selected from a natural cross of Orange Christiana and "a small black melon obtained from a Swedish gardener on the Osage River in Missouri", about 1880. It was introduced by Vaughn's Seed Store in 1887. Some believe that Osage is a selection from Miller Cream, with which it is now synonymous, regardless of its possible origin. Miller Cream was developed by J. D. Miller, of Elmira, N. Y., from a supposed cross of Sills Hybrid and Casaba. About 1890 one of Morrill's associates discovered a single plant in a field of Osage that was believed to be a cross between Osage and Netted Gem. Selection from this plant ultimately produced the variety Hearts of Gold that was introduced about 1895 or 1900. Morrill is said to have sent seed of certain selections from this supposed Osage × Gem cross to Paul Rose for trial, and the latter selected and introduced the varieties Paul Rose (also called Petosky and Osage Gem) about 1898 and Hoodo about 1900. Both were very similar to Hearts of Gold. Hoodoo and Hearts of Gold now are considered synonymous. It is further reported that from Osage Gem D. M. Ferry & Co. selected a strain named

Defender, introducing it in 1901; and that Burrell Gem is a strain of Defender, introduced by the D. V. Burrell Seed Co. in 1904. Burrell Gem and Defender are now synonymous. In 1907 D. M. Ferry & Co. introduced Extra Early Osage, a distinctly earlier variety of the Osage type.

Most varieties that attained importance and later practically disappeared are of unknown origin, although a few are of interest as examples of early purposeful hybridization. Cosmopolitan, introduced in 1894, was from a cross between Green-fleshed Malta and an unnamed netted type. Christiana has been mentioned.

The probable interrelations of some of the important muskmelon varieties are given in figure 2.

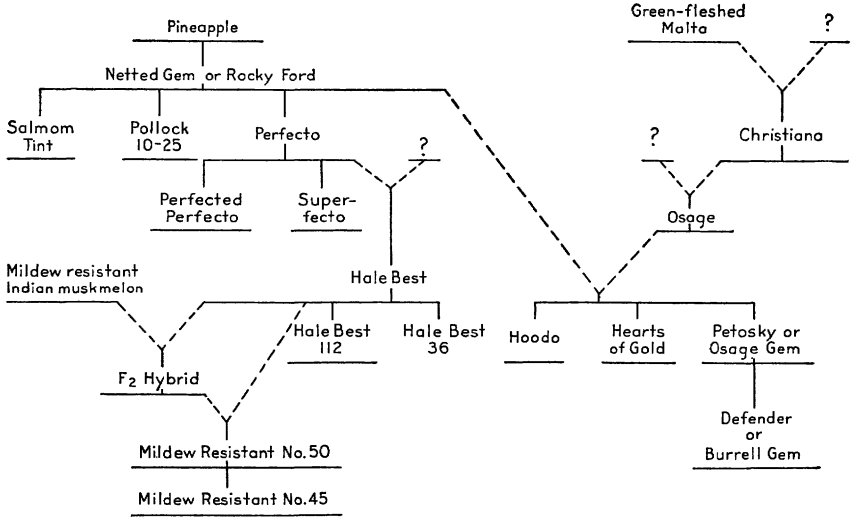

Figure 2.—Probable interrelations of some important muskmelon varieties.

Some old varieties still commonly listed are of unknown origin, but the date of introduction is known. These include Banana (1884), Texas Cannon Ball (1894), Hackensack (1883), Jenny Lind (1866), Montreal (1884), Tip Top (Livingston Seed Co., 1892), Eden Gem (1905).

Among more recent results of introduction and breeding should be mentioned Fordhook (Emerald Gem × Jenny Lind), introduced by W. Atlee Burpee & Co. in 1908. Honey Dew (the old French variety White Antibes Winter) was introduced into the United States about 1900. It not only became popular, but has also often been used as a parent in attempts to introduce its particular quality and flavor into varieties of the cantaloup type. Honey Ball is an important hybrid of Honey Dew and Texas Cannon Ball developed by W. H. Parker, a Texas grower. The original cross was made in 1916 and the variety introduced in 1924 by the Robert Nicholson Seed Co., of Dallas, Tex. Honey Rock is said to have been produced by crossing Champlain, Irondequoit, and Honey Dew. It was introduced about 1920 by Watt Richardson, of Ohio.

The origins of the Persian and the winter (Honey Dew and Casaba) types of melon are unknown. They are very old varieties and were introduced from Europe and Asia.

The Japanese melon is a distinct new variety that has become popular in the local markets of California. It is worthy of trial in other sections with a long growing season. The fruits are fairly large, round, flattened at the blossom end; the rind is tender, thin, pale grayish green with dark blotches, sparsely netted, and very slightly ribbed. The flesh is light salmon in color, soft, and juicy.

Figure 3.—J. T. Rosa (1895–1928), who made important contributions to the breeding of cucurbits, particularly muskmelons and watermelons.

In the new variety, Weaver Special, the white rind of the Honey Ball is combined with the salmon flesh of the shipping-type cantaloup. It was selected from a cross by J. C. Fluke, of C. H. Weaver & Co., in the Imperial Valley, and introduced to the trade in 1933.

Breeding for Disease Resistance

Thirty or more years ago growers noticed differential susceptibility of muskmelon to certain diseases. Hoodoo was mentioned as being resistant to blight.

In 1904 Blinn (*1*), of the Colorado Agricultural Experiment Station, started mass selection in the Rocky Ford variety in efforts to obtain strains resistant to rust (*Macrosporium cucumerinum* Ell. and Ev.). Beginning in 1906, progenies from individual plants and fruits were studied and subjected to selection under severe rust-infection conditions. Although selections were from open-pollinated individuals, marked success was obtained and strains of high commercial value were readily established. The andromonoecious habit of the variety resulted in less cross-pollination and mixture of strains than might be expected to occur in other varieties and species of curcurbits. Blinn also selected for superior shipping and eating quality and developed the first of the salmon tint strains of the Netted Gem type.

In 1925 powdery mildew (*Erysiphe cichoracearum* DC.) suddenly appeared in destructive form on melons in the Imperial Valley of California. Fungicides were found to be inadequate in controlling the trouble, and the crop was seriously injured for the next several seasons.

In searching for resistance, melon varieties and strains from all parts of the world were grown by J. T. Rosa (fig. 3), of the California Agricultural Experiment Station, and I. C. Jagger, of the United States Department of Agriculture, in the Imperial Valley in 1926, 1927, and 1928 (*12*). There was no appreciable success until 1928.

In that year numerous plants were found in several unfixed varieties from India that were practically free from mildew throughout the season, while other plants of the same varieties, and all plants of many other varieties, were badly injured. Unfortunately, the fruits of all the mildew-free plants were commercially useless because of poor shipping and eating qualities. Several commercial varieties were immediately crossed with the mildew-free plants. Resistance to mildew appeared to be inherited as a simple dominant Mendelian character. Back-crossing has considerably hastened the production of varieties that combine the resistance of the Indian melons with

Figure 4.—Comparative test of mildew-resistant and susceptible varieties of muskmelon in the Imperial Valley, Calif.: *A*, Powdery Mildew Resistant Cantaloup No. 45 is practically mildew-free; *B*, Hale Best has leaves largely destroyed by the disease.

the shipping and eating qualities of the American varieties. The development of resistant strains has now largely solved the mildew problem in this area.

Powdery Mildew Resistant Cantaloup No. 50, distributed for commercial trial in 1932, was the first fully resistant variety developed. The fruits are quite variable in size, shape, and quality. It was produced from a cross between the Hale Best variety and one of the resistant plants in the Indian varieties. Individuals from the F_2, or second hybrid generation, were backcrossed to Hale Best, and this was followed by two additional generations of selection. Starting with No. 50, four more generations of selection finally gave Powdery Mildew Resistant Cantaloup No. 45 (fig. 4), grown commercially for the first time in 1936. No. 45 is quite uniform in size, shape, and quality (fig. 5). It resembles Hale Best, but matures somewhat later. The flesh

has even a firmer texture than that of Hale Best. This characteristic gives promise of making it a superior shipping melon in districts adapted to its production.

Powdery mildew-resistant strains of Honey Dew and Honey Ball are being developed for the Imperial Valley under the same project and

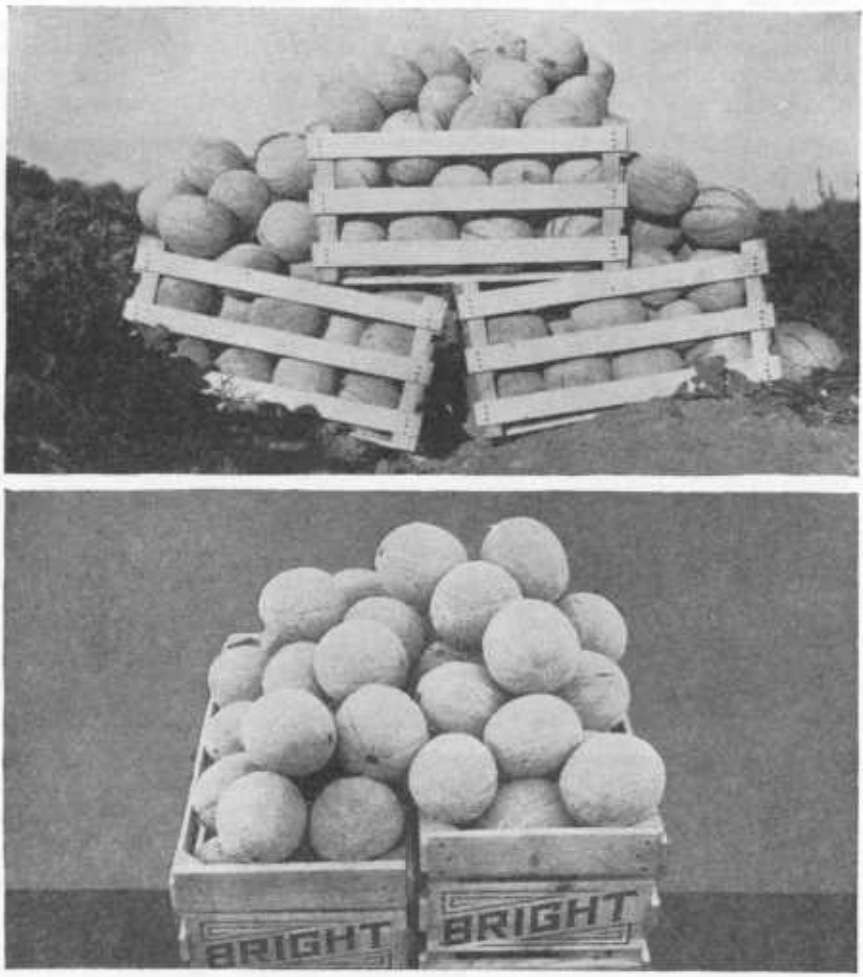

Figure 5.—Powdery Mildew Resistant Cantaloup No. 45, showing type and uniformity of field run melons.

by similar means. Powdery Mildew Resistant Honey Dew No. 60 has been in commercial use in this district since 1935. Outside of freedom from mildew, it has not been quite so satisfactory from a commercial viewpoint as the standard Honey Dew. Backcrossing with Honey Dew and further selection should correct its objectionable characters.

WATERMELONS

THE watermelon, *Citrullus vulgaris* Schrad., is supposed to have been in cultivation some thousands of years, because it had a name in ancient Sanskrit. It is believed to be native to tropical Africa. In 1857, David Livingstone reported it as growing profusely in the Kalahari Desert after an unusually heavy rainfall. Both edible sweet and inedible bitter forms were present. The natives prized the sweet ones highly and made long journeys to obtain them. In parts of Africa the watermelon is a very important crop, furnishing not only food but also drink during periods of drought. In parts of the Union of Soviet Socialist Republics the fruits are important as a staple commodity, being pickled, used as a source of sirup, and eaten fresh. In parts of China certain firm-fleshed varieties are cut into strips, dried, and then made into pickles, sirup, preserves, or glacé sweets. The commercial production and shipping of watermelons to distant markets, to be used fresh, is much more extensive in the United States than anywhere else in the world. Although the crop is grown for home use and local markets in nearly every State, its culture for shipping is confined to the Southern States and to California.

In this discussion the word "type" is occasionally used in referring to groups of varieties of watermelons. It is admitted that the term is loosely used, for there is no single basis for classifying American watermelon varieties that is generally accepted as being adequate. They might be classified according to general features of shape and color, but that would bear no relation to use or to other qualities. A classification according to use, whether for home and local use or for shipping, would denote something concerning eating quality and rind characters, since the favorite varieties of any crop for home and local use are those that are highest in eating quality but are often too perishable for long-distance shipment. Within these two large classes, however, would be found nearly the whole range of colors and shapes. Any attempt to identify a few distinct types, all of which possess numerous qualities in common, presents perplexing difficulties. The problem is to establish a basis of classification in which the individual types are neither too exclusive nor too inclusive to be of practical value.

VARIETAL IMPROVEMENT

A hundred years ago varieties of watermelon were ill-defined and seedsmen's listings usually referred to types rather than to varieties in the modern sense. With the exception of Bradford, which is still listed by a few dealers, no variety mentioned previous to 1850 is listed today, but a few were still common in the early 1900's. Among these were Black Spanish, imported from Portugal in 1827; Carolina, known in 1825; Imperial, Mountain Sprout, Seminole, and Mountain Sweet, introduced by southern growers around 1840 to 1850, or before. Bradford, Clarendon, Odell, Ravenscroft, and Souter all originated in South Carolina sometime prior to 1850.

Although the leading shipping varieties of today are comparatively recent developments, three home and local-market melons still listed by dealers are 60 to 75 years old. Peerless or Ice Cream was introduced in 1860, Phinney Early in 1870, and Georgia Rattlesnake about 1870 by M. W. Johnson, of Atlanta, Ga.

As in many other vegetable crops, the period from 1880 to 1900 marked the beginning of active varietal development and introduction by growers. A large proportion of the varieties listed at present were introduced during that time, and many of them are unsurpassed by later developments except in carrying better quality and disease resistance. The originators or introducers of only a few are now known, and the parentage of even fewer.

W. Atlee Burpee & Co. introduced Cuban Queen in 1881. Round Light Icing appeared in 1885. Kolb Gem, originated by Reuben F. Kolb, of Alabama, was introduced in 1885 by D. M. Ferry & Co. Hungarian Honey apparently was introduced from Hungary about 1885 by persons now unknown. Florida Favorite, said to be a cross between Pierson and Georgia Rattlesnake, was introduced by Girardeau, of Monticello, Fla., in 1887. Dark Icing was brought out by D. M. Ferry & Co. in 1888. Gray Monarch or Long Light Icing appeared in 1889.

Dixie was produced by George Collins, a North Carolina grower, and introduced by Johnson & Stokes in 1890. Stories differ as to whether Cuban Queen or the old Mountain Sweet was one of the parents, but they agree that Kolb Gem was the other. Cole Early was introduced by Cole's Seed Store, Pella, Iowa, in 1892. Sweetheart was developed by a Mr. Wittenmeyer of southern Indiana about 1890 and introduced by D. M. Ferry & Co. in 1894. One of the superior varieties, in eating quality, is Kleckley Sweet, developed by W. A. Kleckley, an Alabama watermelon grower. Its popularity and quality encouraged renaming, and Monte Cristo is one synonym that has persisted. It is said to be from a cross of Boss and Arkansas Traveler (introduced 1892). W. Atlee Burpee & Co. introduced the variety in 1897.

The Chilean, a variety, or perhaps more accurately a type, introduced from the west coast of South America, was first grown in California about 1900. Both white-seeded and black-seeded strains of this variety are now available and are extensively grown in the West. Angeleno was introduced to the trade by Johnson & Musser, of Los Angeles, in 1908, although it had been grown locally for some time. Its origin is obscure, but it is believed to have been selected from a South American stock related to Chilean. White-seeded and black-seeded strains are available, and they possess unusually dark red interior color and high quality. Another variety that gained prominence in the West is Klondike. Its origin is unknown, but it appeared about 1900. Solid-green and striped strains are grown. These three varieties are dominant in California at present and are hardly known elsewhere. Conversely, the important varieties elsewhere are largely unknown in the Pacific coast and southwest areas.

D. H. Gilbert, of Monticello, Fla., introduced Excel in 1906. The origin of Excel is not clear, but it was evidently a poorly fixed intervarietal hybrid. The introducer has stated that the original stock persisted in showing off-shape melons and variations in seed color. A white-seeded strain, introduced in 1926, was said to be free from these objections.

Tom Watson, the dominant shipping melon for the last 20 years or more, originated in Georgia and was introduced in 1906 by the

Alexander Seed Co., Augusta, Ga. It is a large, long, dark-green melon, with a thick, tough rind, that ships well. Unfortunately, however, the quality is only medium.

The original Irish Gray is reported to have been a volunteer plant found growing in an unoccupied stock-feeding pen by Charles Renew, of Rebecca, Ga., in 1913. Some believe the chance seed from which the variety was increased was brought in with feed imported from South America, but there is no proof of such an origin. In 1917 it was being shipped in carload lots, and it was doubtless second in importance in the early 1920's. It has yielded place, however, to Thurmond Gray, a variety originated and introduced by a Mr. Thurmond, a watermelon grower of Perry, Ga. Thurmond Gray first became prominent in 1923.

Stone Mountain originated in Georgia, near Stone Mountain, and was introduced in 1924 by the H. G. Hastings Co., of Atlanta. This melon is round or nearly so, green, of good quality, and a fair shipper. The vines are said to be prolific and resistant to foliage diseases.

The California Agricultural Experiment Station has effected some substantial improvements in uniformity, flesh color, eating quality, and shape of several varieties through the careful selection of lines inbred for several generations. California Klondike (from Klondike) was introduced in 1933, striped Klondike (from stock of the same name) in 1936, and Long Mountain (from Stone Mountain) in 1936.

In 1932 the Minnesota station introduced an unusually early variety, Northern Sweet, that extended the culture of the watermelon farther north. It was developed by inbreeding and selection from a stock introduced from the Union of Soviet Socialist Republics.

The Oscar H. Will Seed Co., of Bismarck, N. Dak., has introduced two varieties designed for growing in the northern Great Plains—Will Sugar in 1889 and Golden Anniversary in 1934. The latter is from a cross of Wikara × Kleckley Sweet, and the other from an unrecorded cross.

Breeding for Wilt Resistance

Until comparatively recently watermelons have been given very little attention by scientific workers. The work of Orton (*17*) is of more than ordinary historical interest, since it is one of the first recorded attempts of a plant breeder to synthesize a commercial variety resistant to a particular disease. Orton crossed the nonedible wilt-resistant citron melon with the edible wilt-susceptible watermelon variety Eden. From a large second-generation hybrid population, selections were made of plants with potentially desirable characters. By further selection a wilt-resistant edible variety, Conqueror, was produced in 1911. This variety never became a popular commercial type on account of unsatisfactory market and eating qualities.

Fusarium wilt is perhaps the most serious watermelon disease today, preventing profitable culture of susceptible varieties in many localities.

Wilt-resistant strains of commercial importance have been developed by Porter and Melhus (*19*) at the Iowa station, by selection from crosses of Orton's wilt-resistant variety Conqueror and certain commercial varieties. The two varieties developed by crossing (Iowa Belle and Iowa King) were about 65 percent resistant compared to the

1-percent-resistant commercial varieties. The exact origin of these two varieties is rather uncertain, but they were selected from apparently chance hybrids between Conqueror and one of the commercial varieties. Porter and Melhus also developed Pride of Muscatine, about 50 percent resistant, by selection of an inbred line of Kleckley Sweet. These three varieties were introduced in 1930.

The Florida station released a new wilt-resistant watermelon in 1936, the Leesburg, developed by M. N. Walker by pure-line selection in Kleckley Sweet grown on heavily infested soil.

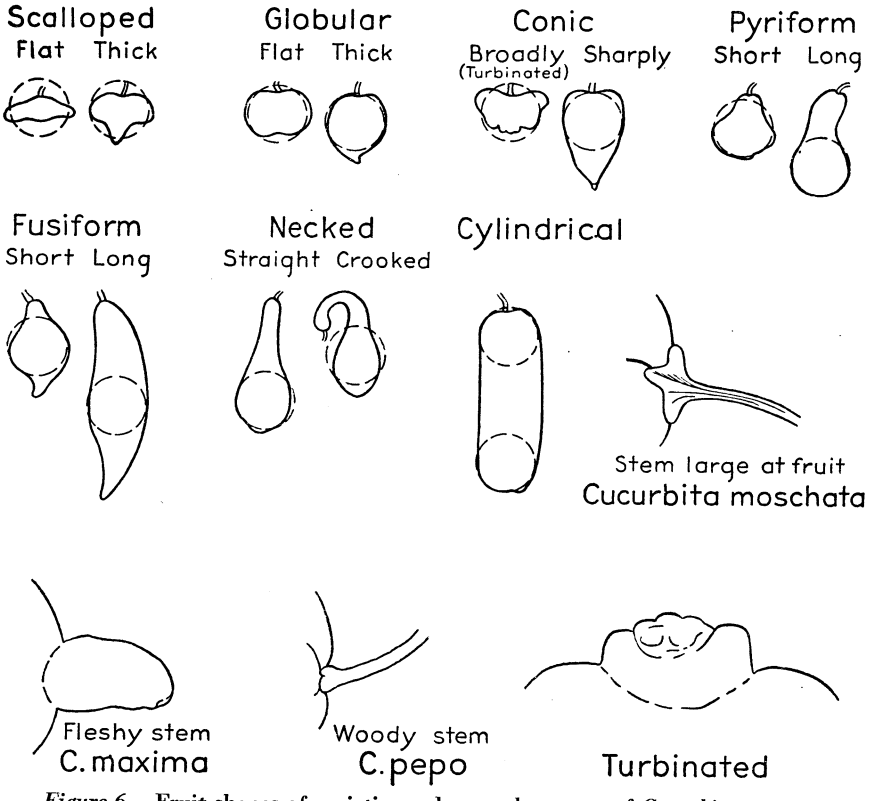

Figure 6.—Fruit shapes of varieties and stem characters of *Cucurbita* species.

The California station in 1936 introduced Resistant Klondike No. 7, a wilt-resistant sort selected from a cross of Iowa Belle × Klondike.

PUMPKINS AND SQUASHES

PUMPKINS and squashes (*Cucurbita pepo* L., *C. moschata* Duchesne, and *C. maxima* Duchesne) are undoubtedly of American origin. Erwin (*6*) states that he has been able to identify fragments of stems, seeds, and fruits of *C. pepo* and *C. moschata* recovered from the cliff dweller ruins of the southwestern United States. With the help of archeologists, Erwin has determined that some of the material is from the basket makers, whose civilization antedates that of the

cliff dwellers; indeed, they were probably the oldest agricultural people of whom we have any record on the North American continent. Vavilov (*30*) believes that *C. moschata* originated in the Mexican-Central American region and that *C. maxima* originated in the Peruvian-Colombian-Ecuadorean area.

Pumpkin and squash varieties are numerous, but many are of local importance only. The fruits of the summer squash are used in an immature stage, while the rind is still tender. There are three important types—scallop, crookneck, and marrow or Italian. Each is represented by a number of varieties. Winter squashes and pumpkins are used when fully mature, after the rind has hardened. Hubbard is the leading type of winter squash, and Connecticut Field and Small Sugar are the leading pumpkins.

As has been previously stated, the differentiation of pumpkins from squashes is very uncertain, because as popularly classified there are both pumpkins and squashes in all three cultivated species of *Cucurbita*. Castetter and Erwin (*2*) have proposed that all varieties belonging to *C. pepo* and *C. moschata* be classified as pumpkins and the varieties of *C. maxima* as squash. Adoption of this classification would mean including the summer squash with the pumpkins, and various other changes in present popular usage. To seed growers and plant breeders the species are important, since varieties of the same species cross very readily, while those belonging to different species practically never cross in nature, contrary to popular belief. Figure 6 illustrates some of the principal differences among these three species of *Cucurbita*, and figure 7 illustrates stem characteristics.

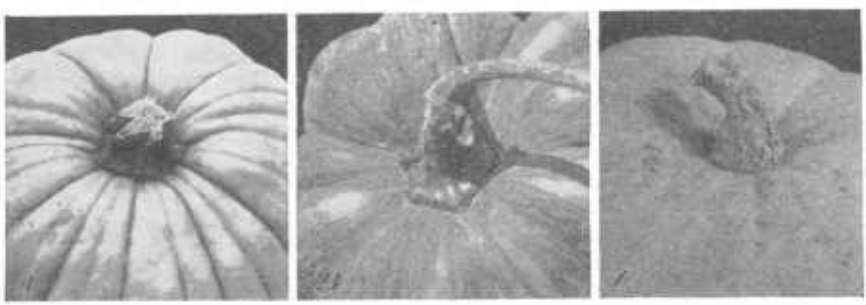

Figure 7.—Stem characters typical of the three species of pumpkin and squash. *A*, *Cucurbita pepo*; note five-angled stem not expanded next to fruit. *B*, *Cucurbita moschata*; stem neither angled nor fleshy but much expanded at attachment to fruit. *C*, *Cucurbita maxima*; stem neither angled nor expanded but fleshy and enlarged, becoming rather spongy when mature.

Varietal Improvement

A study of the origin of our present varieties of pumpkin and squash would require delving into colonial history, and in a number of cases the trail of a variety appears to lead into the history of Indian tribes, where it can no longer be followed.

Large Cheese and Connecticut Field pumpkins were common under those names before the Revolutionary War. Small Sugar is doubtless a hundred years old. The Cushaw has been listed in catalogs for

nearly a hundred years and represents a distinct form, perhaps a variety, that was being grown by the Indians in 1586.

Of the winter squashes, Acorn, a Turban form, was listed over a hundred years ago. Boston Marrow was described by Burr in 1865 as synonymous with Autumnal Marrow. This variety has been widely grown under one of these names in the United States and Europe for a hundred years. John M. Ives, of Salem, Mass., discovered its merits in 1831 and popularized it. He obtained the seed from a friend in Buffalo, N. Y., who in turn is said to have obtained it from a tribe of Indians (unnamed) that visited Buffalo periodically. The Hubbard was introduced to the trade by J. J. H. Gregory, a seedsman of Marblehead, Mass., about 1855. He stated that it had been introduced in the vicinity of Marblehead some 60 years before. The variety is thus conservatively 150 years old and probably older. Marblehead, also introduced by Gregory, is thought to have been imported direct from the West Indies about 1865. Winter Crookneck was described accurately, though not under that name, in 1686 and has been listed in seed catalogs for about a century.

The summer squash varieties are also very old. Both White Bush Scallop and Yellow Bush Scallop were common in 1865, and Burr says the yellow variety had been common for over a hundred years at that time. They were being shipped from the South to northern markets before the Civil War. Yellow Summer Crookneck and various forms of Vegetable Marrow [2] like some grown today have been listed in catalogs for over a century and are believed to have been in common use much longer than that. Three additional varieties—Italian Vegetable Marrow (before 1850), Cocozelle (Vilmorin, 1856), and Mammoth (1826)—were listed by seedsmen and described at the dates indicated; but some or all of them are certainly older, if we may judge by their importance and widespread distribution as stated or implied in the early references. A few variety names of 75 to 100 years ago have almost entirely disappeared from our catalogs and modern literature, but very few, among them Sweet Potato, common about 1850; Valparaiso (1827); and Yokohama, introduced from Japan about 1850.

Is there anything new in squash or pumpkin? Few distinct varieties have been introduced in the last 50 years that are superior, or even equal, to the important old-timers mentioned. Pikes Peak, a winter squash said to have originated in Iowa, was introduced in 1888. Fordhook was introduced by W. Atlee Burpee & Co. in 1889. Des Moines or Table Queen is said to have been introduced from his native country by a Danish farmer about 1900. It was 15 to 20 years later that it became popular and acquired its present name. Delicious, probably a selection from Hubbard, was introduced by Gregory in 1905. Golden Hubbard was introduced in 1896 by a Mr. Harrison of Painesville, Ohio. It was found as a chance plant in a field of Hubbard.

Because of their adaptability to pollination by insects, pumpkin and squash varieties and stocks are difficult to maintain free from mixture. This characteristic also is a prolific source of variation even within

[2] Vegetable Marrow designates a group of summer varieties of *C. pepo* or summer squash characterized by oval or elongate, cylindrical fruits that are harvested for use in a quite immature stage. Cocozelle and Zucchini are common varieties of Vegetable Marrow.

good stocks. In recent years numerous seedsmen have taken greater care in isolating selections made with specific objects in view. As a result, there are now available many good strains that represent improvements in uniformity, earliness, quality, and appearance overthe old parent stocks. The State experiment stations have proved the value of inbreeding in isolating superior, highly uniform strains, and their work indicates the practicability of selecting, from this g roup that has such rich potentialities, strains that will meet almost any set of specifications desired.

Twenty-five years ago Cummings and Stone (*4*), at the Vermont station, initiated their important studies of selection in open-pollinated and inbred lines of Hubbard squash with reference to yield, chemical composition, and quality. The Vermont Hubbard, an inbred line, was introduced in 1914, along with other slightly different strains. Some 6 years later the Vermont workers introduced Long Storage Hubbard, an inbred strain selected specifically for superior storage qualities. About 1921 Bushnell and others of the Minnesota station introduced Kitchenette, an earlier, smaller type of Hubbard produced by inbreeding and selection. In 1932 Krantz and others at Minnesota introduced a very large inbred selection from Hubbard under the name of New Brighton.

In 1932 Yeager and Latzke (*34*), of the North Dakota station, published an account of the development of their new Buttercup squash. This variety is of particular interest because it resulted from a breeding program designed to develop a highly productive, high-quality, highly nutritious squash, adapted to northern Great Plains conditions, as a substitute for the sweetpotato—meaning the real sweetpotato, not the Sweet Potato variety of squash. Inbred selections from a chance cross of Quality×Essex Hybrid best met these specifications. Buttercup is a small (3 to 3½ pounds), yellow, neat, Turban-like variety with flesh of an unusually high solids content (25 percent and higher), containing about 15 percent of starch, 5 percent of sugar, and 2.5 to 3.0 percent of protein. It came from a wide cross and has been difficult to make uniform.

Other varietal improvements have been made to meet specific market demands. In 1936 the California station introduced Gray Zucchini, an inbred strain of Zucchini, and the Connecticut station introduced Connecticut Straight Neck from a Straight Neck inbred× Golden Summer Crookneck.

INHERITANCE IN THE CUCURBITS[3]

CYTOLOGICALLY this family has proved to be less interesting than the vast amount of variation within the group would indicate. Furthermore, the material does not lend itself easily to cytological investigation by the ordinary methods. Although a long list of genera and species has been investigated, there are no established cases of polyploidy, fragmentation, or other gross chromosomal phenomena. Of the cucurbits, cucumbers (*Cucumis sativus*) have 7 pairs of chromosomes, muskmelons (*C. melo*) have 12 pairs, watermelons (*Citrullus vulgaris*) have 11 pairs, and the pumpkins and squashes (*Cucurbita pepo*, *C. moschata*, and *C. maxima*) have 20 pairs (*31*).

[3] This section is written primarily for students or others professionally interested in breeding or genetics.

Inheritance in Cucumber

Information regarding the hereditary behavior of specific characters in the cucumber is very meager. It has been shown that (1) spininess is dominant over spinelessness; (2) black spines are dominant over white ones; and (3) the tendency toward the production of fruit lacking viable seeds (parthenocarpic fruit) is apparently associated with black spines, suggesting that these factors are linked.

Some recent work by Hutchins (*10*) has uncovered an interesting green-flowered variation. This variant is female sterile. As a result, the characteristic can be carried along only in the heterozygous condition. Tests with the normal yellow-flowered form indicate that this green-flowered character is dependent on a single gene recessive to normal yellow, the second-generation hybrid population segregating into 3 normal yellow plants to 1 green-flowered plant.

Inheritance in Muskmelon

Since very early times melons have attracted both the professional and the amateur plant breeder. Sagaret (*22*) in 1824, some 40 years before the time of Mendel, made a series of interesting genetic studies with melons. He was undoubtedly one of the earliest forerunners of modern geneticists. His work very definitely shows that he had the idea of contrasting unit characters in his crosses. However, he failed to follow his results into the F_2 generation or to analyze them mathematically. From a cross of two distinctive varieties, Sagaret found that in the F_1 yellow skin was dominant over white skin, netted epidermis over smooth epidermis, pronounced ribbing over smooth ribbing, and acid flavor over sweet flavor.

Lumsden (*16*) attempted to determine the inheritance of the following contrasting fruit characters: Yellow versus green skin color, round versus obtuse-elliptical shape, large versus small seeds, ribbed versus nonribbed, netted versus smooth surface, and large versus small fruit size. He worked with commercial stocks of unknown purity, but they were apparently heterozygous for the characters studied, for he reported segregation into numerous gradations together with the appearance of both parental types in the F_1. No definite conclusions can be drawn from his work. His own conclusions concerning dominance of specific characters are not supported by his data. With the possible exception of skin color, it would appear that all the characters he observed were determined by multiple factors.

Rosa (*21*) has obtained ratios indicating monohybrid segregation of certain characters; that is, the monoecious condition was dominant over the andromonoecious condition; the tricarpellate ovary was dominant over the five-carpellate ovary. In some earlier work, Rosa (*20*) had been able to demonstrate that pollen from different sources has little if any immediate effect on the qualitative characters of the fruit.

As all varieties of muskmelons are notoriously cross-fertile, most of the commercial varieties are highly heterozygous. It is possible to isolate superior strains by selection and inbreeding. These methods have been adopted to stabilize varieties of commercial importance.

A carefully planned inbreeding program at the California station, continued in a few cases to the seventh generation with Salmon Tint, Hale Best, Honey Dew, Honey Ball, and Casaba varieties, has clearly demonstrated that no deleterious effects result from this amount of inbreeding.

Inheritance in Watermelon

Recently a comprehensive, systematic breeding program at the California station has produced much information that will be of value in dealing with problems of watermelon breeding in the future. Besides developing an effective pollination technique, Porter (*18*), has studied the biology of fruit setting in relation to certain environmental factors and has made observations on the effects of inbreeding.

With reference to inbreeding, strains were isolated that were comparatively homozygous for fruit-shape factors and for a number of fruit characteristics—for example, flesh color, texture of flesh, solidity of fruit, etc. Most varieties show no loss of vigor after four to five generations of inbreeding.

In the case of watermelon wilt, the phenomena of resistance and susceptibility are relative. The commercial varieties are as a rule very highly susceptible to wilt; the inedible varieties (as stock citron), on the other hand, are more or less resistant. No variety observed to date seems to be completely immune.

Rosa (*21*) found that the majority of watermelon varieties are monoecious and a few varieties are andromonoecious. Crosses of varieties representing these two types indicated that the difference was monogenic, the monoecious condition being dominant.

Porter and Poole, at the California station, have determined the mode of inheritance of a number of characters in the watermelon. All of the characters investigated gave monohybrid ratios, and there was no evidence of linkage among any of them. Their experiments indicate that (1) in flesh color, red is dominant over yellow; (2) in seed-coat color, black is dominant over white and tan; (3) in fruit-skin color, dark green is dominant over striped and white; (4) in rind, toughness is dominant over tenderness; and (5) in fruit shape, short is dominant over long.

Inheritance in Pumpkin and Squash

The question of whether pumpkins and squashes will cross has always interested amateur gardeners. Considerable confusion has arisen from an imperfect understanding of botanical relationships. There is no accepted basis for distinguishing pumpkins from squashes. Botanically they belong to three species of the genus *Cucurbita*. As popularly classified there are both pumpkins and squashes in all three species.

Castetter and Erwin (*2*) and Erwin and Haber (*7*) have shown that varieties belonging to the same species cross very readily, while those belonging to different species practically never cross in nature. However, cross-pollinating certain varieties belonging to *Cucurbita pepo* with varieties of *C. moschata* has produced partially fertile hybrids. Until recently only sterile hybrids, or complete failure to develop fruits, had resulted from cross-pollinating varieties of *C. maxima* with varieties of *C. pepo* and *C. moschata*. Van Eseltine, at the New York

(State) station, has recently obtained fertile hybrids of reciprocal crosses of *C. pepo* and *C. moschata* and of *C. maxima* and *C. moschata*. Dana, of the Bureau of Plant Industry, in working for curly top resistance in squash varieties, obtained hybrids of *C. moschata* and *C. maxima* that were self-fertile in the F_1 but male-sterile in the F_2. He has backcrossed the hybrid to both parents and obtained fertile backcross progenies.

Early attempts at a genetic analysis of this genus have proved to be practically worthless, chiefly because the investigators were using heterozygous material in their experiments. They underestimated the value of establishing pure lines as a primary factor in securing reliable results in genetic experiments.

The first attempt at a careful genetical analysis of *Cucurbita* was made by Sinnott and Durham (*26*). They used several varieties of *C. pepo*. After being inbred for several generations, the original types were evidently homozygous, as evidenced by their behavior. At this point, using the inbred material, an investigation of the inheritance of certain characters was initiated. From their results the several characters studied appear to be inherited, as indicated in table 1.

TABLE 1.—*Inheritance in summer squash fruits, Cucurbita pepo (after Sinnott and Durham)*

Contrasting characters	Behavior in F_1	Segregation in F_2
Exterior "ground" color:		
White *v.* yellow	White	3 white to 1 yellow (certain crosses produce 15:1).
Yellow *v.* green	Yellow	3 yellow to 1 green.
White *v.* green	White	12 white to 3 yellow to 1 green.
Exterior striping:		
White fruits, nonstriped *v.* green-striped.	do	43 white and 9 green-striped.
Yellow fruits nonstriped *v.* white-striped.	White-striped	Complex.
Flesh color:		
White *v.* cream	White	3 white to 1 cream.
Surface:		
Smooth *v.* medium warty	Warty	3 warty to 1 smooth.
Smooth *v.* very warty	do	15 warty to 1 smooth.
Shape:		
Disk *v.* sphere	Disk	9 disk to 6 sphere to 1 long. Different crosses gave different results. Maybe 1, 2, or more factors involved. In some, the situation is very complex.

Sinnott and his coworkers (*27*, *28*) have greatly extended this analysis, particularly with regard to the genes governing sizes and shapes in fruits. In general, these characters appear to be determined by numerous factors, so their inheritance is complex and not completely clear. It has been shown that in the cucurbits inbreeding up to at least 7 to 10 generations does not result in a general decline in the vigor of the plants. This behavior is in distinct contrast to that of corn, onions, etc., where inbreeding immediately brings about a decline in vigor.

Hutchins (*11*), at the Minnesota station, has shown in different color types of Hubbard squash (*Cucurbita maxima*) that green is partially dominant to blue. The F_1 was intermediate in color, and the F_2 and backcross populations segregated as for a single factor. Lotsy (*15*) showed that in *C. maxima* exterior fruit-color inheritance

is for the most part complex. In a cross of Turban (a red strain) × Green Hubbard, the F_2 segregated into 3 reddish to 1 green. The dominance of the red was incomplete. In a cross of Turban × Silver Gray, a very wide assortment of colors occurred in the F_2. Lotsy also showed that the Turban character (fig. 2), caused by incomplete enclosure of ovarian tissue by receptacle or torus tissue, is due to two dominant genes. Turban × Green Hubbard gave an F_2 segregation of 15 Turban forms to 1 non-Turban form.

LITERATURE CITED

(1) BLINN, P. K.
1908. CANTALOUPE BREEDING. Colo. Agr. Expt. Sta. Bull. 126, 10 pp., illus.

(2) CASTETTER, E. F., and ERWIN, A. T.
1927. A SYSTEMATIC STUDY OF SQUASHES AND PUMPKINS. Iowa Agr. Expt. Sta. Bull. 244, pp. [107]–135, illus.

(3) CUMMINGS, M. B., and JENKINS, E. W.
1928. PURE LINE STUDIES WITH TEN GENERATIONS OF HUBBARD SQUASH. Vt. Agr. Expt. Sta. Bull. 280, 29 pp., illus.

(4) ——— and STONE, W. C.
1921. YIELD AND QUALITY IN HUBBARD SQUASH. Vt. Agr. Expt. Sta. Bull. 222, 48 pp., illus.

(5) EDMOND, J. B.
1931. SEASONAL VARIATION IN SEX EXPRESSION OF CERTAIN CUCUMBER VARIETIES. Amer. Soc. Hort. Sci. Proc. (1930) 27: 329–332.

(6) ERWIN, A. T.
1931. NATIVITY OF THE CUCURBITS. Bot. Gaz. 91: 105–108, illus.

(7) ——— and HABER, E. S.
1929. SPECIES AND VARIETAL CROSSES IN CUCURBITS. Iowa Agr. Expt. Sta. Bull. 263, pp. [343]–372, illus.

(8) HABER, E. S.
1929. INBREEDING THE TABLE QUEEN (DES MOINES) SQUASH. Amer. Soc. Hort. Sci. Proc. (1928) 25: 111–114.

(9) HIBBARD, A. D.
1934. METAXENIA IN THE APPLE AND SQUASH. Amer. Soc. Hort. Sci. Proc. (1933) 30: 140–142.

(10) HUTCHINS, A. E.
1936. THE INHERITANCE OF A GREEN FLOWERED VARIATION IN CUCUMIS SATIVUS. Amer. Soc. Hort. Sci. Proc. (1935) 33: 513.

(11) ———
1936. THE INTERACTION OF BLUE AND GREEN COLOR FACTORS IN HUBBARD SQUASH. Amer. Soc. Hort. Sci. Proc. (1935), 33: 514.

(12) JAGGER, I. C., and SCOTT, G. W.
1932. CANTALOUPES. 6th Internatl. Cong. Genetics Proc. v. 2, p. 359.

(13) JONES, H. A., and ROSA, J. T.
1928. TRUCK CROP PLANTS. 538 pp., illus. New York.

(14) LLOYD, J. W.
1935. MUSKMELON. *In* Bailey, L. H., The Standard Cyclopedia of Horticulture, v. 2, pp. 2027–2031, illus. New York.

(15) LOTSY, J. P.
1920. CUCURBITA-STRIDJVRAGEN. II. EIGEN ONDERZOEKINGEN. Genetica 2: 1–21, illus.

(16) LUMSDEN, D.
1914. MENDELISM IN MELONS. N. H. Agr. Expt. Sta. Bull. 172, 58 pp., illus.

(17) ORTON, W. A.
1911. THE DEVELOPMENT OF DISEASE-RESISTANT VARIETIES OF PLANTS. 4th Conf. Internatl. Genetique, Paris, pp. 247–265.

(18) PORTER, D. R.
1933. WATERMELON BREEDING. Hilgardia 7: 585–624, illus.
(19) ——— and MELHUS, I. E.
1932. THE PATHOGENICITY OF FUSARIUM NIVEUM (EFS.) AND THE DEVELOPMENT OF WILT-RESISTANT STRAINS OF CITRULLUS VULGARIS (SCHRAD.) Iowa Agr. Expt. Sta. Research Bull. 149, pp. [123]–184a, illus.
(20) ROSA, J. T.
1927. DIRECT EFFECTS OF POLLEN ON FRUIT AND SEEDS OF MELONS. Amer. Soc. Hort. Sci. Proc. (1926) 23: 243–248.
(21) ———
1928. THE INHERITANCE OF FLOWER TYPE IN CUCUMIS AND CITRULLUS. Hilgardia 3: [233]–250, illus.
(22) SAGARET, M.
1826. CONSIDERATIONE SUR LA PRODUCTION DES HYBRIDS DES VARIANTES ET DES VARIANTES EN GENERAL, ET SUR CELLES DE LA FAMILLE DES CUCURBITACEES EN PARTICULIER. Ann. Sci. Nat., Bot. (i) 8: 294–314.
(23) SCOTT, G. W.
1933. INBREEDING STUDIES WITH CUCUMIS MELO. Amer. Soc. Hort. Sci. Proc. (1932) 29: 485.
(24) ———
1934. SEX RATIOS AND FRUIT PRODUCTION STUDIES IN BUSH PUMPKINS. Amer. Soc. Hort. Sci. Proc. (1933) 30: 520–525.
(25) ———
1935. OBSERVATIONS ON SOME INBRED LINES OF BUSH TYPES OF CUCURBITA PEPO. Amer. Soc. Hort. Sci. Proc. (1934) 32: 480.
(26) SINNOTT, E. W., and DURHAM, G. B.
1922. INHERITANCE IN THE SUMMER SQUASH. Jour. Heredity 13: 177–186, illus.
(27) ——— and DURHAM, G. B.
1927. A FACTORIAL ANALYSIS OF CERTAIN SHAPE CHARACTERS IN SQUASH FRUITS. Amer. Nat. 61: 333–344.
(28) ——— and HAMMOND, D.
1930. FACTORIAL BALANCE IN THE DETERMINATION OF FRUIT SHAPE IN CUCURBITA. Amer. Nat. 64: 509–524, illus.
(29) TIEDJENS, V. A.
1928. SEX RATIOS IN CUCUMBER FLOWERS AS AFFECTED BY DIFFERENT CONDITIONS OF SOIL AND LIGHT. Jour. Agr. Research 36: 721–746, illus.
(30) VAVILOV, N. I.
1935. [BOTANICAL-GEOGRAPHICAL PRINCIPLES OF SELECTION.] 60 pp. Moskva and Leningrad. [Translation in U. S. Dept. Agr., Bur. Plant Indus.]
(31) WHITAKER, T. W.
1930. CHROMOSOME NUMBERS IN CULTIVATED CUCURBITS. Amer. Jour. Bot. 17: 1033–1040, illus.
(32) ———
1931. SEX RATIO AND SEX EXPRESSION IN THE CULTIVATED CUCURBITS. Amer. Jour. Bot. 18: 359–366.
(33) ———
1933. CYTOLOGICAL AND PHYLOGENETIC STUDIES IN THE CUCURBITACEAE. Bot. Gaz. 94: 780–790, illus.
(34) YEAGER, A. F., and LATZKE, E.
1932. BUTTERCUP SQUASH, ITS ORIGIN AND USE. N. Dak. Agr. Expt. Sta. Bull. 258, 19 pp., illus.